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14. ABSTRACT

The Network of Networks (NoN) model, which is a neurobiologically motivated smart algorithm co-developed by the PI, has been applied for rapid and accurate image processing of forward and side scan sonar images in turbid environments. The model has also been used as a platform for rapid distributed communications for autonomous vehicles. Both of these applications build upon unique features of the NoN for reconfigurable computing across multiple scales of organization, and the approach has direct relevance to several enabling technologies for Future Naval Capabilities.

15. SUBJECT TERMS

neural networks, sonar, autonomous vehicles, image enhancement, communications

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Reconfigurable Network of Networks for Multi-Scale Computing

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CONCISE SUMMARY

The final phase of the project, which ended April 9, 2002, consisted of refinement and testing of biologically inspired reconfigurable Network of Networks (NoN) using versions 2.0, 2G.0 and 3.0 of the Autonomous Vehicle SYStem (AVSYS) model developed with this research grant. A series of reports have been prepared, with peer reviewed manuscripts being published. A preliminary U.S. patent filing on the AVSYS model was followed with a full patent application. Connections were established to continue work that develops and applies intelligent networking and biologically motivated communication to Navy problems relevant for decentralized and collaborative systems of autonomous vehicles. Applications of the principal findings of this project were also applied to ongoing research for NASA concerning smart, autonomous and reconfigurable systems for biomedical support of human space travel.

LONG-TERM GOALS

1. Transition and implementation of the research to advanced projects for biologically inspired sensing, intelligent autonomy, reconfigurable networking and novel human-machine interfaces.

2. Expand research and development to other areas relevant for DoD, NASA and advanced medical systems.

OBJECTIVES

1. Identify neural system features relevant to (a) image enhancement & object identification in turbid conditions, and (b) communications for reconfigurable networks across scales

2. Implement these features for (a) sonar image processing, and (b) systems of model autonomous vehicles (AVs)

3. Develop and deliver algorithms for (a) mine detection, classification and identification (algorithm fusion), and (b) demonstrations of simulated AV network dynamics based on neural system rules and properties

APPROACH

The approach is to refine and apply the NoN computing architecture, based on prior theoretical work and ongoing experimental research in neuroimaging and neurocomputation, to topics of Navy relevance. These topics include enabling technologies for FNCs in areas of situational awareness, networking and communications, and intelligent autonomy. The applications are by means of computer demonstrations utilizing the capabilities of NoN systems. These capabilities include, but are not limited to: (a) a platform for computing at multiple scales simultaneously; (b) high capacity connectivity; (c) dynamically reconfigurable networks; (d) distributed, collaborative planning and data integration; (e) adaptability to changing environments; and (f) sensory processing, decision making, action and control in autonomous settings.

WORK COMPLETED

1. Deliverables: AVSYS v 2.0, 2G.0, 3.0 software, GUI, demonstration and documentation for networks of UAVs and UUVs search, with relevance to communications, reconfigurable networking and intelligent autonomy

2. Elucidation of neurally inspired rules that govern reconfigurable networks

3. Proof-of-principle demonstrations that the rules in #2 can be implemented using the deliverables in #1

RESULTS

Results and deliverables associated with each of the objectives have been described in previous reports. In addition to these results, modes 1 and 2 for the AVSYS model Versions 2.0 and 3.0, respectively, were shown to yield complementary processes for implementing dynamic reconfiguration in autonomous vehicle (AV) networks. Mode 1 is a moderately fast, conflict-resolution mode whereby AVs autonomously reconfigure themselves to perform a coordinated task. Surprisingly, large amounts of information transfer impede the performance of the network. Mode 2 is a rapid, aggressive mode with a traditional sigmoid response relating communication among AVs with the aggregate performance of the network. Preliminary results suggest added value in utilizing both modes in parallel.

IMPACT/APPLICATIONS

This project demonstrates the added value of a system of systems approach relative to a single large scalable system. There are numerous applications for autonomous intelligent agents which can transiently group together to perform a function and then dissipate. The project provides insight and rules into how reconfigurable networks form and successfully carrying out goal-directed cooperative behavior.

TRANSITIONS

This research has inspired the formation of two Massachusetts based companies, eNCog Inc and NewcoGen One-IT Inc, for the purpose of fostering technology transfer of prior and pending patents.

RELATED PROJECTS

- Development of a system of systems, autonomous platform for sensing, interpreting and delivery of care for the "smart" medical system for human space flight. Sponsor: National Space Biomedical Research Institute under subcontract from NASA.

REFERENCES

- *No references reported.*

PUBLICATIONS

Journal Articles.

- Sha, D.D. & Sutton, J.P. (2001). Towards automated enhancement, segmentation and classification of digital brain images using Networks of Networks. Information Sciences, 138, 45-77. *(peer reviewed)*
- Sha, D., Kennedy, D., & Sutton, J. (In press). Neurocomputing for automated analysis of digital brain images. Artificial Intelligence in Medicine. *(peer reviewed)*
- Sutton, J.P. & Jamieson, I. (In press). Reconfigurable networking for coordinated multi-agent sensing and communications. Information Sciences. *(peer reviewed)*

Books or Chapters.

- Sha, D.D. (2001). Towards Automated Segmentation and Classification of Digital Images. Ph.D. Thesis. MIT.
- Sutton, J.P. & Jamieson, I. (2001). Reconfigurable network of neural networks for autonomous sensing and analysis. Proceedings of the Fifth International Conference on Cognitive and Neural Systems. 64.
- Sutton, J.P. & Jamieson, I. (2002). Reconfigurable networking for coordinated multi-agent sensing and communications. Proceedings of the Sixth Joint Conference on Information Sciences. 36-39.
- Sutton, J.P. & Strangman, G. (In press). The behaving human neocortex as a dynamic network of networks. Hecht-Nielsen R, ed. Theories of the Cerebral Cortex. New York: Springer Verlag.

Technical Reports.

- Sutton, J.P. & Jamieson, I. (2000). AVSYS: Coherent behavior among weakly interacting search vehicles [Computer Software Documentation]. MGH Neural Systems Group.
- Sutton, J.P. & Jamieson, I. (2001). AVSYS Version 2.0: Coherent behavior among weakly interacting search vehicles [Compter Software Documentation]. MGH Neural Systems Group.
- Sutton, J.P. & Jamieson, I. (2001). AVSYS Version 3.0. Coherent behavior among weakly interacting search vehicles [Compter Software Documentation]. MGH Neural Systems Group.
- Sutton, J.P. & Jamieson I. (2001). The Grid Model - AVSYS Version 2G.0. Coherent behavior among weakly interacting search vehicles [Compter Software Documentation]. MGH Neural Systems Group.

PATENTS

- Sutton, J.P. & Jamieson, I. Neurally inspired distributed computing for reconfigurable networks. MGH Invention Disclosure. 2001 March 28. Preliminary US Patent Filing. 2001 June 1. Full Patent Filing 2002 and Patent Pending.

ADDITIONAL INFORMATION

HONORS

- PI appointed Acting Team Leader for Technology Development, National Space Biomedical Research Institute; PI is already Team Leader for Smart Medical Systems, National Space Biomedical Research Institute (see National Geographic, cover story January 2001).
- PI appointed Director, National Space Biomedical Research Institute (Science 18 January 2002, Nature 31 January 2002)

STATISTICS

Statistics were entered, and they are:

0 Number of Degrees Granted

PI/CoPI Information

	Minority	Non-Minority	Total
Women	0	0	0
Men	0	1	1
Total	0	1	1

Grad Students Information

	Minority	Non-Minority	Total
Women	0	1	1
Men	0	0	0
Total	0	1	1

Post Doctoral Information

	Minority	Non-Minority	Total
Women	0	0	0
Men	0	0	0

Total	0	0	0

***Under-represented or minority groups include Blacks, Hispanics, and Native Americans. Asians are not considered an under-represented or minority group in science and engineering.*

****Supported at least 25% this year on contract/grant.*

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